RAPID MULTIPLICATION OF BAMBOO (*BAMBUSA HETEROSTACHYA*): THE EFFECT OF CULM AGE AND LENGTH OF CUTTINGS ON SPROUTING

B.N. Nuertey[1], A. Opoku[2,3] and I. Danso[1]
[1]*Oil Palm Research Institute, CSIR, P. O. Box 74, Kade, Ghana*
[2]*Department of Crop and Soil Sciences, KNUST, Kumasi, Ghana*
[3]*International Institute of Tropical Agriculture (IITA), P.M.B. 5320, Ibadan, Nigeria*

ABSTRACT
The effect of age and length of bamboo culms on sprouting of culm cuttings was studied in a field experiment at the Oil Palm Research Institute (OPRI), Kusi. The study was conducted as a factorial combination of four age groups (<6 months, 6 months to 1 year, 1 year to 2 years and 2 years to 3 years) and three lengths (1 node, 2 nodes and 3 nodes) of culm cuttings. The 12 treatment combinations were laid out in a randomized complete block design and replicated three times. The cuttings made from 1-2 years old culms bearing triple nodes produced significantly (P<0.05) more number of shoot (146) than all the other age group – length of culm combinations. The 1-2 years old culms were found to be superior to the other age groups and produced 69 shoots while 0, 29 and 20 shoots were produced by the less than 6 months old, 6 months to 1 year old and 2 to 3 years old culms, respectively. Whereas only 6 and 24 shoots emerged from the cuttings with single and double nodes, cuttings with triple nodes produced as many as 58 shoots. The study recommends the use of culms cuttings with triple nodes made from 1-2 years old culms for rapid multiplication of bamboo stock.

INTRODUCTION
Bamboo (*Bambusa heterostachya*) is a giant, woody, tree-like grass which has a long history as a versatile and widely used renewable resource. In southeast Asia and sub-Saharan Africa, bamboos provide construction materials for shelter, tools and implements for agriculture, pulp for paper, and materials for handicrafts, furniture, bags, baskets and plywood. Besides these versatile uses, man, probably from pre-agricultural times, used tender bamboo shoots for food. In addition, the extensive shallow root system of bamboo makes it a useful plant in watershed management and soil conservation and thereby playing essential role in environmental protection (Singh and Singh, 1999).

Bamboo is a quick-growing and hardy species occurring on a wide range of soil conditions with particularly luxuriant growth on well drained soils. As a perennial woody grass it is known to be a good substitute for wood, consequently proper management of bamboo resources could contribute greatly towards afforestation while meeting the great demands for wood products. Bamboo production has contributed immensely to the economic growth of countries in southeast Asia with vibrant bamboo industries. China for instance, earns some 1.5 billion US dollars annually from the export of bamboo and bamboo products (Maoyi, 2005). Even though bamboo has enormous economic and ecological benefits it remains a lesser non-exportable forest resource which could be exploited without any hindrance in Ghana.

The most endearing aspect of bamboo as a raw material is that it comes in a 'ready-to-use' form and so usually requires little processing. It is therefore very appropriate that bamboo processing factories such as the Assin Fosu Bamboo Company and others are springing up across the country to harness bamboo into finished products. To adequately feed these factories and meet other demands, it is necessary to augment bamboo production by protecting natural regeneration as well as raising plantations.

Irregular supply or lack of viable seeds for many bamboo species has resulted in the continued dependence on vegetative propagation. Koshy and Jee (2001) identified high pollen sterility, absence of natural pollination and inhibition of pollen tubes in the stigma tissue to be major factors accounting for lack of fruit set in golden bamboo, *Bambusa vulgaris.* Various methods of vegetative propagation like offset planting, layering, macroproliferation, culm and branch cuttings are used for the propagation of bamboos. Although these propagules may be difficult to handle and transport due to their bulky nature, refined techniques of vegetative propagation have been found to cut costs of bamboo plantations (Banik, 1994).

The culm is the above ground stem which grows from the underground rhizomes. It is segmented with nodes that bear one or more buds. Earlier reports by Seethalakshmi *et al.* (1988) and Gonzales *et al.* (1991) indicated that rooting of culm cuttings could be induced by using growth regulating substances such as indoleacetic acid (IAA), indolebutyric acid (IBA), naphthalene acetic acid (NAA) and coumarin.

The length and age of the culms used for cuttings together with environmental considerations such as soil, temperature and moisture are the most important factors affecting the survival and performance of propagules in the field (Anon, 2003). Length of culm cuttings as measured by the number of internodes, largely affects the number of shoots emerging from the propagules since bamboo plant propagated with culm cuttings sprouts from physiologically viable bud. Furthermore, age of culm greatly affects the vigor of buds to produce new shoots. Banik (1993) observed that cuttings from very young culms decayed easily while very old cuttings failed to sprout due to loss of viability of buds.

Except for homestead cultivation, bamboos have rarely been planted on large scale in Ghana, so, information on bamboo culms as planting materials is lacking. In an effort to bridge the information gap on bamboo propagation techniques, this study was conducted with the general objective of identifying the most appropriate culm cuttings for rapid multiplication of bamboo stock. The specific objective was to determine the effect of age of culms and length of cuttings on sprouting of bamboo to identify the optimum age and length of culm cuttings for propagation.

MATERIALS AND METHODS

Study Site

The experiment was set up at OPRI Kusi (06.00 N, 001.45 W). The soils of the experimental field were derived from forest ochrosols occurring on a gently slopping topography. The Soils of the Nzema series occurred in the upper to middle slope and colluvial soils of the Kokofu series on the lower parts (Asiamah and Senayah 1991). Prior to the establishment of the experiment the area was cropped with maize.

Experimental design and treatments

The experimental treatments consisted of factorial combinations of four age groups of culms (less than 6 month, 6 month – 1 year, 1 – 2 years, and 2 – 3 years) with three lengths of culm cuttings (1 node, 2 nodes and 3 nodes) in a randomized complete block design. The treatments were replicated three times. Cuttings were planted horizontally at a depth of 5 cm on raised bed. Each bed was 30 cm high and measured 0.8 m x 5.4 m. The cuttings were planted 20 cm from the edges of the beds and spaced at 20 cm within rows and 40 cm between rows on the beds. Fifty cuttings constituted a plot.

Determination of culms age

Clumps selected from bamboo plantation established at OPRI for an earlier study were used to produce propagules for this study. Red bands, 10 cm in width were made on the 7th internode of all culms that emerged between July 2001 and June 2002 by painting these sections with red indelible ink. Similarly, culms that emerged from July 2002 to June 2003, July 2003 to January 2004 and February 2004 were identified by yellow, blue and black bands respectively. All culms marked with colour bands were harvested in June 2004.

Cultural practices

Fertilizer was applied as NPK 15:15:15 at 400 g/bed (333 kg/ha) which was broadcasted and worked into the beds prior to planting of cuttings. The beds were copiously watered every other day to keep the soil moist. Weeds were hand-picked fortnightly from the beds.

Data collection and analysis

The impacts of the age of culms and the number of internodes on regeneration of bamboo were evaluated in terms of sprouting of new shoots over the six month duration of the experiment. A cutting was considered sprouted when the 'leaf axis' sheath appears above ground. Emerged shoots were tagged and used in estimating the number of sprouts on cumulative basis. A cutting was considered dead if it failed to emerge by end of the 6th month after planting (MAP) and showed no evidence of sprouting at nodal region upon uprooting.

The tiller to cutting ratio, which is the number of tillers (new shoots) developed by a cutting was calculated by relating the total number tillers on a plot to total number of cuttings planted on a plot.

Data were analyzed statistically using the analysis of variance procedure of GenStat (Release 4.2, Discovery Edition 2) following checks for the normality of data and homogeneity of variance. The means of the various treatments were separated using a single degree of freedom orthogonal contrast.

RESULTS

Shoot emergence was significantly ($P<0.001$) affected by age of culms, number of nodes on cuttings and their interactions. A positive ($P<0.001$) interaction between number of nodes and age of culms was found only when the culms used as propagules were older than 6 months (Table 1). Thus, whereas culms less than 6 months old could not produce any shoots irrespective of the number of nodes on the cuttings, the number of sprouts recorded in each age bracket increased with increasing number of nodes (Table 1).

Triple nodes (N_3) cuttings made from 1-2 years old culms (A_3) produced the largest number of shoots (146 shoots/plot). Table 1 also indicates that among the cuttings that sprouted, the least number of shoots (6 shoots/plot) emerged from 2-3 years old cuttings with single node (A_4N_1).

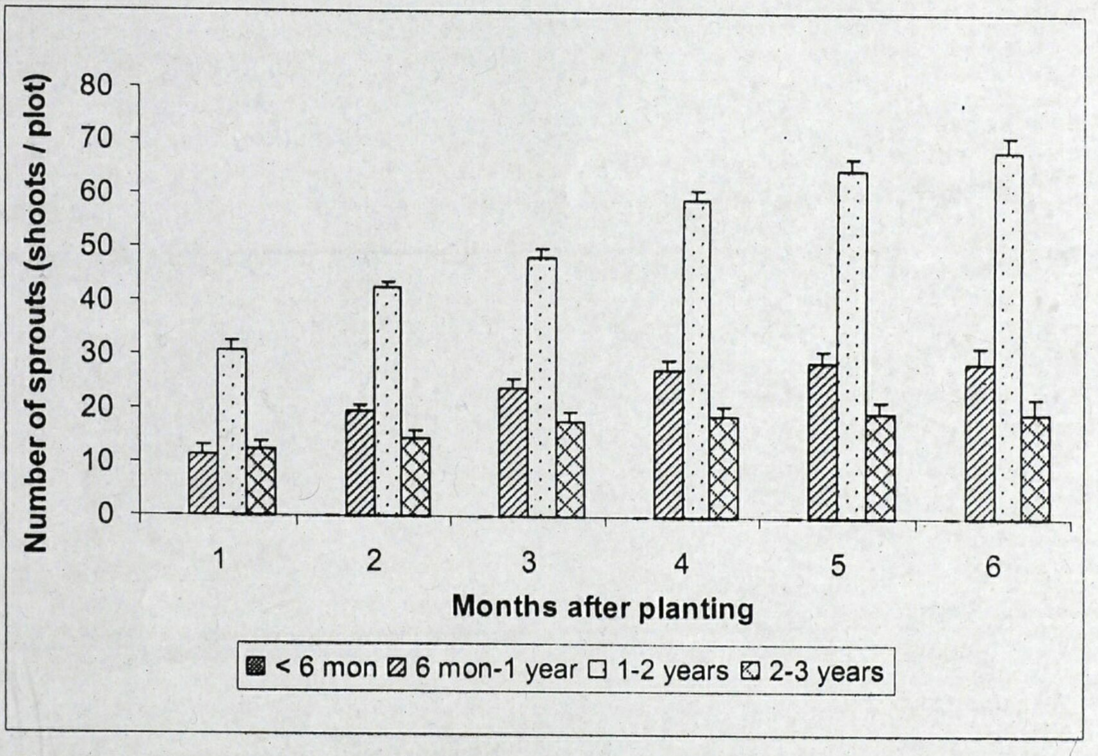
Sprouting of the culms under 6 months old was very poor as none of the 50 cuttings developed any aerial shoots throughout the study. A number of these cuttings were uprooted and checked for evidence of root formation but most of them were found to be dead (Table 2 and Fig. 1).

The number of shoots emerging from 6 months -1 year old cuttings rose steadily from 12 shoots/plot during the first month to 28 shoots/plot after the 4th month. Compared to 2-3 years old culms cuttings, the 6 months -1 year old cuttings developed significantly ($P < 0.05$) larger number of new shoots during the last three months (Fig. 1). On the whole, the 1-2 year old cuttings produced larger ($P < 0.001$) number of new shoots (69 shoots / plot) than other planting materials (Fig. 1).

Whereas a large number of the 6 months-1 year old and 2-3 years old cuttings (21 and 30 cut-

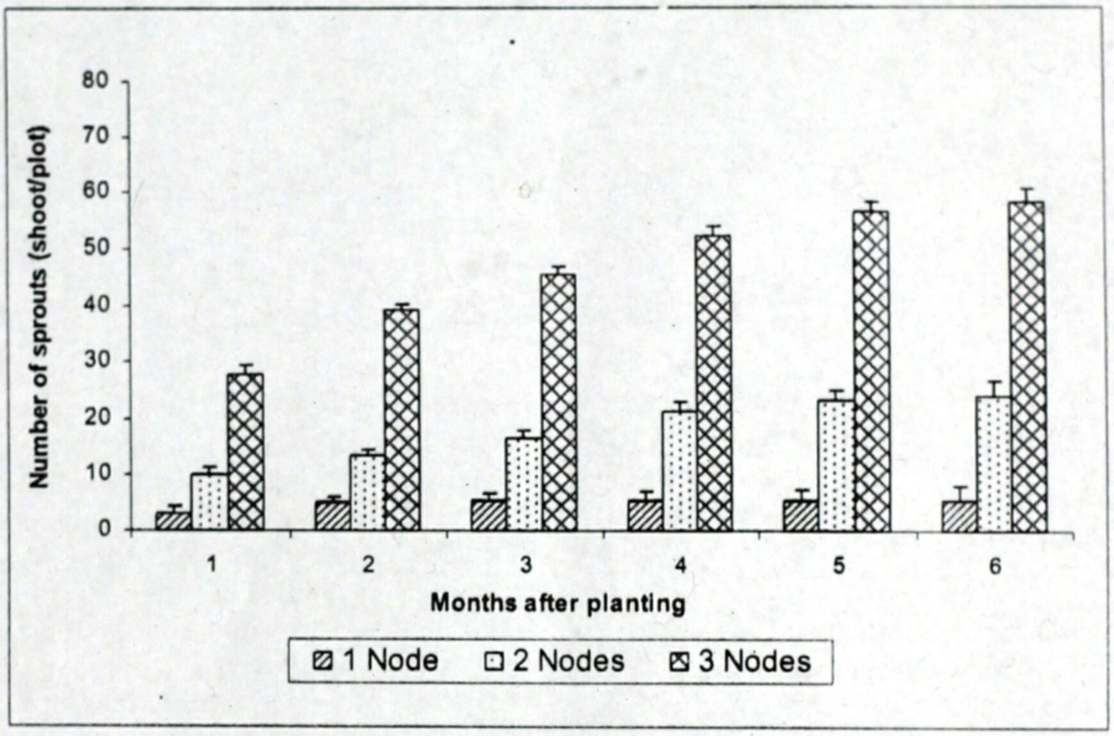
Table 1: The combined effect of culm age and length on bamboo sprouting (shoots / plot)

Treatments		Months after planting					
Age of culms (A)	Number of nodes/cutting (N)	1	2	3	4	5	6
< 6 months	single	0	0	0	0	0	0
	double	0	0	0	0	0	0
	triple	0	0	0	0	0	0
6 months-1 year	single	2	7	8	9	9	9
	double	7	15	20	21	22	22
	triple	26	37	44	53	55	55
1-2 years	single	5	7	7	7	7	7
	double	23	25	27	44	49	52
	triple	65	94	110	126	139	146
2-3 years	single	5	6	6	6	6	6
	double	11	14	19	20	22	22
	triple	21	25	28	31	32	32
SE		2.7	2.1	3.0	3.2	3.5	5.0
LSD (5%)		8.0	6.2	8.6	9.2	10.4	14.7
CV (%)		34.6	19.0	22.6	20.6	21.6	29.7
F test and probabilities							
Age (A)		<.001	<.001	<.001	<.001	<.001	<.001
Nodes (N)		<.001	<.001	<.001	<.001	<.001	<.001
A x N		<.001	<.001	<.001	<.001	<.001	<.001



Values are the means of 3 replications, and vertical bars indicates SE of the means

Figure 1: Effect of age of culms on sprouting of bamboo



Values are the means of 3 replications, and vertical bars indicates SE of the means

Figure 2: Effect of number of nodes on sprouting of bamboo

tings/plot respectively) failed to sprout, all the 1 -2 years old cuttings sprouted with some developing multiple shoots as indicated by the tiller : cutting ratio of 1.37 (Table 2).

The number of new shoots that emerged increased exponentially with increasing number of nodes. Cuttings with single nodes produced the least number of new shoots while cuttings with triple nodes developed the largest number of new shoots throughout the study (Fig. 2). The duration of shoot emergence corresponded greatly to the number of nodes on the cuttings.

Table 2: Effect of age of culms on sprouting of cuttings at the end of the study

Age of culms	No sprouts (shoots / plot)	Dead cuttings (%)	Tiller : cutting
< 6 months (A_1)	0.0	100	0.00
6 month-1 year (A_2)	28.9	42.2	0.58
1-2 years (A_3)	68.6	0	1.37
2-3 years (A_4)	19.8	60.4	0.40
SE	2.90	5.80	0.06
CV (%)	29.7	32.0	29.7
F test and contrast probabilities			
(A_1+A_2) versus (A_3 +A_4)	<.001	<.001	<.001
A_1 versus A_2	<.001	<.001	<.001
A_3 versus A_4	<.001	<.001	<.001

Table 3: Effect of length of culms on sprouting of cuttings at the end of the study

Length of cuttings (nodes / cutting)	No sprouts (shoots / plot)	Dead cuttings (%)	Tiller: cutting
Single (N_1)	5.5	89.0	0.11
Double (N_2)	24.1	51.8	0.48
Triple (N_3)	58.3	0.0	1.17
SE	2.5	5.0	0.05
CV (%)	29.7	32.0	29.7
	F test and contrast probabilities		
N_1 versus (N_2 +N_3)	<.001	<.001	<.001
N_2 versus N_3	<.001	<.001	<.001

The single node cuttings attained the peak shoot emergence (6 shoots/plot) by 3 MAP whereas the double and triple node cuttings attained their peak shoot emergence (24 and 58 shoot/plot respectively) at the 5 MAP and 6 MAP respectively.

Most of the single and double node cuttings (44 and 26 cuttings/plot respectively) failed to bear any aerial shoot. On the contrary, all the triple node cuttings sprouted with some developing multiple shoots as indicated by the tiller : cutting ratio of 1.2 (Table 3).

DISCUSSION

Proliferation of shoots from culms older that 6 months increased within each age group with increasing number of nodes as depicted by the significant ($P < 0.05$) interaction between age and numbers of nodes. Our results indicated that the largest number of shoots emerged from triple node cuttings made from 1 – 2 years old culms. This observation accords with Koshy and Gopakumar (2005) assertion that culms cuttings made of 2-3 nodes segments bearing healthy buds are suitable for the propagation of clump-forming bamboos when culms selected are not older than 2 years.

Culms cuttings consisting of three nodes exhibited a superior sprouting capacity of 100% as opposed to the 48% and 11% obtained from culms cuttings with double and single nodes respectively. The observed positive correlation between the number of nodes and sprouting capacity could be attributed to the presence of bud from which new shoots sprout. In addition, the nodal diaphragm preserves the viability of the bud by supplying it with water and nourishment (Liese, 1985). The excellent sprouting of the culms cuttings with triple nodes recorded in this study confirms the results obtained by Vivekanandan (1987) in a related study on *Bambusa heterostachya*. On the contrary, Bumalong and Tamolang (1980) working on *Bambusa tulda* Roxb found the emergence of shoots from cuttings with single node to be comparable to those with double and triple nodes. The differences in the species used for these studies (*heterostachya* and *tulda* respectively) may account for the discrepancy in these results.

The shriveling and decaying of cuttings less than 6 months old could be attributed to the high moisture and starch content, Fangchum (2000) and the absence of lignin in their epidermal and hypodermal cells (Lybeer *et al.*, 2006). Lin *et al.* (2002) studying lignin heterogeneity among the various age classes of bamboo found a steady increase in lignin deposition from 1st year up to 7 years after establishment. Consequently, the observed improvement in emergence of shoot (58%) from 6 months to 1 year old culms relates to the lignifications of these culms upon aging, which improved their resistance to decay. In addition, thickening and hardening of the nodal diaphragm associated with the maturation process enhanced the viability of the buds.

Clearly, the optimum age range of bamboo culms cuttings suited for propagation was 1 to 2 years as shown by the 100% sprouting. In addition, some of these cuttings developed multiple shoots as indicated by the tiller to cuttings ratio of 1.4. This observation supports the assertion by several authors (Varmah and Bahadur, 1981; Banik, 1995; Boontawee, 1988 and Anon, 2003) that one-to two-year old culms cuttings are good propagules as they have active and vigorous buds capable of producing new shoots.

The finding that shooting capacity declined to 40% when culms used as cutting were 2 to 3 years old is consonant with Banik's (1984) report that shoot emergence diminished when culms cuttings are older than two years. Anon (2003) identified loss of viability of buds to be the main factor accounting for the reduced shooting capacity in older culms. Banik (1980) on the other hand, emphasized that for a bamboo shoot to emerge the propagule must develop the culm, rhizome and root. Failure to develop any of these structures leads to deterioration. He further enumerated slowness of buds to break dormancy and meager development of roots to be typical problems associated with culms aged 3 years or more. Even though it is undisputable that the age of culms used for cuttings is a major determinant for successful sprouting, it is extremely difficult to ascertain the exact age of bamboo culms unless they have been properly marked during their emergence. However, certain diagnostic morphological characters like colour and presence or absence of leaf sheath, number of leaf scars and branching pattern make it easier to estimate age. The young culms are greener while the leaf sheaths are still present (Anon, 1990). Earlier report by McClure (1966) indicated that a year-old culm has no leaf scars, a 2-year-old culm has one leaf scar and a 3-year-old is characterized by two leaf scars.

In sum, 1- 2 years old culms cuttings bearing 3 nodes is the most effective propagation material for rapid multiplication of bamboo stock.

CONCLUSION

In conclusion, the biological parameters considered in this study have shown that *Bambusa heterostachya* can be propagated by culm cuttings. For excellent shoot emergence and quick regeneration of bamboo however, the culms used should be 1- 2 years old and be cut into at least 3 nodes units.

ACKNOWLEDGEMENTS

The authors express their profound gratitude to the staff of Agronomy Division, CSIR – OPRI who helped to execute the study and collect data. This paper is published with the permission of the Director, CSIR – OPRI.

REFERENCE

Anon (1990)."Propagation of Bamboos by Culm Cuttings", KFRI Irf. Bull., No. 8 (BIC Series 1), Kerala Forest Research Institute, Peechi,India (5 pages).

Anon (2003). The Bamboo Production Committee. Philippines Recommends for Bamboo Production, Philippine Council for Agriculture, Forestry and Natural Resources Research and Development (PCARRD) Los Baños, Laguna, pp. 23-26.

Asiamah, R. D. and Senayah, J. K. (1991). Report on detailed survey of lands of Oil Palm Research Institute, Kusi Eastern Region, p. 42.

Banik, R.L. (1980). "Propagation of Bamboos by Clonal Methods and by Seeds", in Bamboo Research *in Asia,* G. Lessard and A. Chouinard (eds.), IDRC, pp. 139-150.

Banik, R.L. (1984).'Macropropagation of Bamboos by Pre-rooted and Pre-rhizomed Branch Cuttings", *Bano Biggyan Patrika* (Bangladesh Forest Research Institute, Chittagong), 13: 67- 73.

Banik, R.L. (1993). "Selection and Multiplication of Bamboos for Industrial Planting Programmes", in Proc. of Workshop on Production of Genetically Improved Planting Materials for Afforestation Programmes (Coimbatore, India.June 18-25, 1993), K. Vivekanandan et al (eds.), pp. 76-97.

Banik, R.L. (1994). "Review of Conventional Propagation Research in Bamboos and Future Strategy", pp. 115-142, in Constraints to Production of Bamboo and Rattan IDRC/INBAR, Bangalore, India

Banik, R.L. (1995). A manual for vegetative propagation of Bamboos, INBAR Technical Report No. 6, INBAR, FORTIP and Bangladesh Forest Research Institute, pp. 1 –66.

Boontawee, B. (1988). Status of Bamboo Research and Development in Thailand, in Recent Research on Bamboos, Proc. of International Workshop *on* (Eds Rao, A. N., Gnanaharan R. and Sastry C.B.) Cochin, India IDRC pp 21-22.

Burmalong, A. A. and Tamolang, F. N. (1980). "Bamboo Research in the Philippines", in *Bamboo Research in Asia,* G. Lessard; and A. Chouinard (eds.), IDRC. pp. 69-80.

Fangchum, Z. (2000). China TCDC International Training Course on Bamboo Technology. China National Bamboo Research Center, Hangzhou, P.R China. pp. 95-98.

Gonzales, L. L., Marcos, J., Ouimio, J. and Nicolas, S. U. (1991). "Propagation of Kawayan-Kiling through Split-Culm Cuttings", *Canopy International,* 17: 6-7.

Koshy, K. C. and Jee, G. (2001). Bamboo collection at Tropical Botanic Garden, Palode *Current science* 81: 375–378.

Koshy, K.C. and Gopakumar, B. (2005). An improvised vegetative propagation technique for self-incompatible bamboos. *Current science* 89: 1474-1476.

Liese, W. (1985). Bamboos: biology, silvics, properties, utilization. Deutsche Gesellschsft fur Technische Zusammenarbeit, Eschborn, Germany. 132 pp.

Lin, J.X., He, X.Q., Hu, Y.X., Kuang, T.Y., Ceulemans, R. (2002). Lignification and lignin heterogeneity for various age classes of bamboo (Phyllostachys pubescens) stems. *Physiologia Plantarum* 114: 296–302.

Lybeer, B., Koch, G., Van Acker, J. and Goetghebeur, P. (2006). Lignification and Cell Wall Thickening in Nodes of Phyllostachys viridiglaucescens and Phyllostachys nigra. *Annals of Botany* 97: 529–539.

Maoyi, F. (2005). Criteria for selection of superior bamboo varieties, propagation and plantation establishment. Research Institute of Subtropical Forestry CAF, Fuyang, China. (http://*www.ipgri.cgiar.org/publication/HTMLpublications/572/ch18.htm.)*

McClure, F.A. (1966). The *Bamboos: a Fresh Perspecfive,* Harvard University Press, Cambridge, Mass.

Seethalakshmi, K. K., Surendran, T. and Somen C.K. (1988) Vegetative Propagation of *Ochlandra travancorica* and 0.*scriptoria* by Culm Cuttings in *Recent Research on Bamboos* Proc. of International Workshop *on* (Eds Rao, A. N., Gnanaharan R. and Sastry C.B.) Cochin, India IDRC pp.128 132

Singh, A.N. and Singh J.S. (1999), Biomass, net primary production and impact of bamboo plantation on soil redevelopment in dry tropical region. *Forest Ecology and Management* 199: 195-207.

Varmah, J.C. and Bahadur, K.N. (1981). Country report and staus of research on bamboo in India. *Indian Forest. Rec.* (Bot.) 6 : 128

Vivekanandan, K. (1987). Bamboo research in Sri Lanka. *In* Rao, A.N.; Dhanarajan, G.; Sastry, C.B. ed., Recent Research on Bamboo. Proceedings of the International Bamboo Workshop, Hangzhou, China, 6-14 October 1985. Chinese Academy of Forestry, Beijing, China; Interna-tional Development Research Centre, Ottawa, Canada. pp. 61-66.